THE ADAPTABILITY OF WISCONSIN CONDITIONS TO CONCRETE ROADS

BY

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INTRODUCTION

The most important question confronting the highway engineer is the type of road to build that will give the maximum amount of service for the money, and, considering the different conditions to which the road will be subjected.

This question of the proper improvement of roads is of ancient origin. Extensive military roads radiating from Rome were constructed and among these, "The Appian Way," having a length of 360 miles, can be found today in fairly well-preserved condition.

Farmers throughout the country have for a period of years constructed and maintained their town highways. The road commissioner was elected, and he superintended the construction work. Each tax-payer worked out his share of assessment by furnishing teams, materials and services. This method of construction was never satisfactory, and upon the advent of the swiftly moving automobile became unbearable. The automobile used for pleasure, or the heavily loaded truck, the motor cycle and to some extent iron-shod horses hauling heavily loaded wagons with narrow tires are the agents which make maintenance costs a large item in highway construction.

Because of the fact that everyone will keep the centerof the road except on passing, the old form of earth and macadam roads are soon rutted along these paths. Water collects in these ruts and finds its way to the foundation, thereby causing softening of the sub-grade and heavy maintenance costs.

The United States Office of Goods Roads have issued a report covering roads built in the United States up to 1909. Out of 2,199,645 miles of highways, only 8.66%were improved. During 1910 State aid and construction located 4,278 miles of improvement. In 1911 the available data shows that from the 49 states and territories, 13 gave aid on their roads, two gave convict services, 5 gave engineering service, 1 state gave convict broken stone, 28 gave more or less direct aid.

The number of automobiles in the United States in 1912, including commercial vehicles, was 1,013,975. The total number of machines in use during the same time was nearly 1,000,000. The total mileage of improved roads at the close of 1912 was approximately 222,081. That is, there were nearly five automobiles to each mile of improved road.[1]

The automobile traffic in all forms is rapidly increasing, as is shown by the following table.

TABLE I [2]
TRAFFIC CENSUS IN MASSACHUSSETTS

YEAR	NO.STATIONS	AVERAGE NO. OF VEHICLES	% TOTAL VEHICLES PER DAY
1909	238	96.1	39
1912	156	222	63

This shows an increase in automobile traffic of 131% in three years.

1. U.S.Dept. Agriculture, Office of Public Roads, Bulletin #48
2. Ibid.,

EFFECT OF MODERN TRAFFIC ON MACADAM HIGHWAYS

The waterbound macadam is the most easily disintegrated by the action of motor traffic. The suction of the pneumatic tires, and the propelling action of their driving wheels, loosens the binder of the road. The dust is drawn up and blown from the road by a strong draught passing under the car.

With the bituminous type of macadam the effect is not so marked or rapid. The bituminous materials bind the courses of stone together more securely. The action of the automobile tire is to first remove the wearing coat of sand or small pebbles. The top stone are later left exposed, making a very rough surface to ride over.

Many methods have been used in spreading bituminous materials on the road surface. Mechanical spreaders have been used and have proved unsatisfactory. The regulation of the flow of binder has given very serious trouble. It is essential in spreading binder that the machine move at a uniform rate of speed. This is impossible with the use of horses, as propelling forces. Also dirt or other foreign matter often found in the barrels fillsup the valves and give an unequal distribution of material.

Hand spreading is now used extensively in New York State with fairly good results. One side of the stone is well covered with material while the side away from the spreader is somewhat slighted.

It is very difficult to obtain an equal distribution of

of bituminous material. Places are left where very little binder is spread. Ravelling will start there, and water will eventually reach below the surface forming a soft place, needing prompt repair.

Oil macadam has been constructed in New York State with very poor results. The additional cost over waterbound macadam with little increased value as to life does not warrant its adoption as a permanent road. It has the advantage of being dustless, but as in the case of waterbound macadam, the automobile soon destroys the wearing course leaving the top stone exposed to the weather.

EXPERIMENTATION

Much experimentation on macadam and concrete has been carried on by the United States and State governments. Probably the most thorough investigation of macadam and concrete highways has been carried on by the United States Office of Good Roads at Chevy Chase.[1] Here the traffic was heavy, composed both of heavily loaded traffic cars and also pleasure automobiles.

The road was first constructed in 1911. Several sections of bituminous and waterbound macadam were constructed. No available data is on hand at present as to the wear of these roads.

The concrete road was laid during the last few months and was composed of experiments I and II, Bituminous concrete sec-

1. Cement Era, Oct. 1913.

tions and experiment III concrete mixed with oil. No expansion joints were used, and road made twenty feet in width and six inch average depth. The subgrade of the road was made to conform to the finished surface. The concrete mixture, 1:1½:3, was thoroughly tamped into place. The sand used in the mixture was required to pass a ¼ inch screen and gravel ¼" to 1½" inclusive. The limestone was the portion retained by ¼" screen and left by ½" screen. Concrete was covered with sand and kept wet for seven days. The highway was then thoroughly cleaned and a coat of bitumen 1/3 to 1/2 gallon per square yard spread on the clean surface.

Five pints of oil per bag of cement was used in the oil concrete. Cracks occured in the concrete approximately 23 feet apart. The gravel aggregate contained more cracks than crushed stone.

The oil weakens the strength of the concrete but makes it more impervious.

The conclusions drawn from oil concrete at present show that this method of construction has no advantage that would warrant its adoption.

Cost of Chevy Chase Road.

Plain concrete,	Gravel , ...	$1.3985	per square yard
	Limestone, ...	1.4285	" " "
Oil Concrete,	Gravel, ...	1.4766	" " "
	Limestone, ...	1.5066	" " "

TABLE II[1]

TESTS ON MACADAM HIGHWAYS

Date of Original Construction	No. of Tests	Original Crown	Present Crown
1895	7	0.694"	0.500"
1896	9	.583	.514
1897	12	.645	.500
1898	7	.625	.500
1899	2	.688	.625

EXPERIMENTAL WATER BOUND MACADAM[2]

HUDSON AVENUE, MONROE COUNTY, N.Y.

This road, .65 miles in length, was constructed in 1900. The surface was 16 feet wide with foundation course 4 inches thick and a top course of crushed trap rock 2 inches in thickness. The road cost $7,242.67 to improve or $11,370 per mile. The traffic carried by this road was exceedingly heavy, and it was necessary to repair the road from time to time. The total cost of maintenance has been $1,045 per mile per year.

EXPERIMENTAL PAVEMENT CONSTRUCTED ACCORDING TO HASSAM IDEA[3]

Old macadam roadbed spiked and reshaped stone was then spread to the depth of 8 inches. It was properly rolled, and the grout used being 2 bags of cement to 2 bags of sand, and 20 gallons of water. The pavement was 14 feet wide and cost

1. Massachussets Highway Commission, Report of 1901.
2. N.Y.State Commission of Highways, 1911.
3. N.Y.State Commission of Highways, 1910.

$1.50 per square yard, without expansion joints. During the cold weather cracks appeared across the roadway every 50 to 100 feet. The former waterbound macadam roadway was rutted considerably and crown badly worn when Hassam pavement was constructed.

DEVELOPMENT OF CONCRETE ROADS

History

The first pavement on record was laid in Bellefontaine, Ohio, in 1893-1894. It was laid on two wide streets surrounding the court house square. The base of 4 inches of concrete, 1 part of cement to 4 parts of gravel. A two inch top course 1 part of cement to 1 part of sand. No expansion joints were used, but the pavement was cut into blocks of 5 foot square. Considerable wear developed along the longidutinal joints. The total maintenance to date has been $200.00. Cost $2.25 per square yard.

Following is a tabular digest of important concrete pavements constructed in United States,

TABLE III

LOCATION	YEAR BUILT	TYPE	SQUARE YDS.	THICKNESS IN INCHES	PROPORTIONS	COST
Richmond, Ind.	1896	2-course	5000	6"	-	$1.62
	1902	2-course	5000	6"		1.40
	1903	2-course	5000	6"		1.28
	1904	2-course	5000	6"		1.43
	1906	2-course	3000	6"	1:8 1:1:1	1.28
	1907	2-course	3000	6" 1"		1.27
Des Moines, Ia.	1909	2-course	5000	6½ 1½	1:2:5 1:1:1	1.62
Mason City, Ia.	1909	2-course	8000	5 2	1:5 1:1:1	-
Boise, Id.	1910	1-course	20000	8	1:3:7	1.155
Kansas City	1910	1-course	5000	6	1:2½:4½	1.29

TABLE III (Continued)

LOCATION	YEAR BUILT	TYPE	SQUARE YDS.	THICKNESS INS.	PROPORTIONS	COST
Fort Dodge, Ia.	1910	2-course	26000	5 2	1:2:5 1:1:1	$1.59
Osage, Ia.	1910	2-course	40000	5 2	1:2½:5 1:2	1.39
Ann Arbor, Mich.	1910	Dollar-way	27000	4½ 1½	1:1½:& 1:2	.80
Wayne Co., Mich.	1910	1-course	50000	6	1:2:4	1.04 to 1.71
Douglas Co. Ia.	1910	1-course	28000	5	1:3:5	1.27 to 1.62
Eldora, Ia.	1912	2-course	40000	5 2	1:2½:5 1:2	1.23
Marshall-town, Ia.	1912	2-course	60000	5 2	1:2:5 1:2	1.08
Mason City, Ia.	1912	2-course	49800	5 2	1:2:5 1:2	1.23
Highland Park, Mich.	1912	2-course	12600	5 2	1:3:5 1:2½	1.35
Kansas City,	1912	1-course	266500	6	1:2½:4½	1.04
Kansas City	1913	1-course	250000	6	1:2½:4½	.98 to 1.05
Hampton, Ia.	1913	2-course	45600	5 2	1:2½:5 1:2	1.205

TABLE IV

STATEMENT OF CONCRETE PAVEMENTS BUILT IN WISCONSIN.

LOCATION	YEAR BUILT	TYPE	SQUARE YARDS	THICKNESS INS.	PROPORTIONS	COST SQ.YD.
Fond du Lac	1909	2-course	17000	5 1½	1:2½:5 1:1	$1.31
Fond du Lac	1909	2-course	70000	5 1½	1:2½:5 1:1	1.10 to 1.32
Appleton,	1909	2-course	16000	5 2	1:3:6 1:1½	1.30
Menasha	1909	2-course	12000	6 2	1:2:4 1:1½	.95
DePere	1910	2-course	21000	6 1¾	1:3:5 1:1½	1.31
Fond du Lac	1910	2-course	49000	5 1½	1:2½:5 1:1:1	1.09 to 1.27
Green Bay	1910	2-course	6000	6 1¾	1:3:5 1:1½	1.35
Menasha	1910	2-course	17000	6 2	1:2:4 1:1½	1.225
Burlington	1911	2-course	12200	5 1½	1:2:4 1:2	1.06
Fonddu Lac	1911	2-course	11000	5 1½	1:1½:5 1:1:1	1.25
Menasha	1911	1-course	7000	6	1:3:5	1.27
Sheboygan	1911	2-course	20000	6 2	1:3:5 1:1½	1.20 to 1.33
Green Bay	1912	2-course	26000	6 1¾	1:3:5 1:1½	1.25
Columbus	1912	Dollarway	2800	6	1:2½:4	1.22
Sheboygan	1912	2-course	25600	6¾ 1¾	1:3:5 1:1½	1.25
So.Milwaukee	1912	1-course	12000	6	1:2:4	1.35
Kenosha Co.	1913	1-course	6300	6	1:2:3½	.67*
Kenosha Co.	1913	1-course	32600	7	1:2:3½	1.06
Kenosha Co.	1913	1-course	11300	7	1:2:3½	.79
Kenosha Co.	1913	1-course	5280	6½	1:2:3½	.96

* does not include grading.

WAYNE COUNTY ROADS

In the year 1893 the constitution of Michigan was amended after which a county road law was adopted making the county instead of the township the unit of building and maintaining roads.

In 1909 a tax of 1/4 mill was imposed giving $85,000 to be used in the construction of roads. This was followed the next year by a 1/3 mill tax, and in 1911 by a 1/2 mill tax. Wayne County then bonded itself for $2,000,000 to be spent for road purposes in five years.

First only waterbound macadam or gravel roads were constructed, but these were soon found unsatisfactory. An investigation was then made for the purpose of discovering any available and satisfactory road metal. A study of the experience of smaller towns with their side-walks, bridge floors and other concrete structures was made with the result that concrete was finally adopted.

In 1909 concrete was substituted for macadam and used in experimental work. The first experimental road was constructed in two courses. The bottom course was of a 1:2½:5 mixture, and 4" in thickness. The wearing coat was made 2½" thick of a 1:2:3 mixture. The road was built on sub-soil of gravel.

The second experiment was constructed under the specifications given above, but on a clay sub-soil.

The following statement gives a list of the concrete roads constructed in Wayne County in the year 1910:

TABLE V.[1]

CONCRETE ROADS CONSTRUCTED IN WAYNE COUNTY IN 1910

ROAD	LENGTH: MILES	WIDTH FT.	THICKNESS & PROPORTIONS: BOTTOM--COURSE	---TOP	COST PER SQ.YD.
Wayne Rd.So.	0.502	10	6"-1:2:4	None	$ 1.39
Woodward Ave	1.210	18	4"-1:2½:5	2½"-1:2:3	1.20
Mt.Elliot Rd	0.909	12	4"-1:2½:5	2"--1:2:3	1.29
Michigan Ave	2.412	18	7½"-1:2:4	None	1.27
Grand River	1.616	16	4"-1:2½:5	2½"-1:2:3	1.16
Van Dyke	1.000	15	4"-1:2½:5	2-1:2:3	1.27
River	0.740	15	6"-1:2:3	None	0.82
Mack	0.309	15	6"-1:2:4	None	1.34
Eureka	1.000	12	6"-1:2:4	-	)
Gratiot	1.700	12	- -	-	)Not completed
Fort	0.500	-	- -	-	)Sept.30, 1910

TABLE VI[2]

CONCRETE ROADS CONSTRUCTED IN WAYNE CO., MICH., 1911

Fort (a)	0.500	12	6"-1:2:4	None	$1.38
Eureka	1.000	12	6"-1:2:4	None	1.28
Gratiot	3.236	16	7"-1:1½:3	None	1.35
Grand River	2.51	16	7"-1:1½:3	None	1.74
Wayne Rd.So.	0.500	15	7"-1:1½:3	None	1.15
Van Dyke	1.052	15	7"-1:1½:3	None	1.61
Michigan Ave	7.523	16-20	7"-1:1½:3	None	1.43
Mt. Elliot	0.455	15	7"-1:1½:3	None	1.58
Mack	0.263	15	7"-1:1½:3	None	-
River	3.5	15	7-1:1½:3	None	-

1. 4th Annual Rep. Wayne Co.   2. 5th Annual Rep. Wayne Co.

TABLE VII[1]

ROADS BUILT IN WAYNE COUNTY TO SEPT. 30, 1912.

Name	Mileage	
Jefferson	1.65	
Mack	0.592	
Gratiot	3.326	
Van Dyke	2.806	
Mt. Elliot	3.538	
Woodward	2.213	
Grand River	10.132	
Michigan	22.023	
Wayne So.	1.002	
Fort	2.637	
Eureka	4.135	
River	10.781	
Total Mileage		65.745

The only repair required on these concrete roads has been refilling of contraction joints with tar and sand on the roads first constructed. These joints were not protected by armor plate. The cost of maintenance up to that time would not exceed $100.

In 1913 there were approximately 20 miles of concrete roads laid using the standard specifications of a 1:1½:3 mixture, 1 course construction, using a crown of 1/100th of the width of the road metal. The shoulders are four feet in

1. Sixth Annual Report of Wayne County.

width and constructed of gravel. The gravel is placed in 3 inch layers and each is thoroughly compacted by rolling before the succeeding one is placed. After at least three weeks the shoulders are further consolidated by a roller as approved by the Board of Commissioners. There is 820,000 square yardsof concrete pavement in Wayne County at present.

TABLE VIII[1]

TABLE SHOWING THE CONDITION OF WAYNE COUNTY CONCRETE ROADS IN AUGUST, 1913.

NAME OF ROAD	YEAR: BUILT	DEFECTIVE SECTIONS: LONG'L CRACKS	TRANSVERSE CRACKS	DIAG'L. CRACKS	HOLES	% DEF.
Woodward Ave.	1909	209	80	2	46	76.5
Grand River Ave	1909	61	11	1	3	27.9
Woodward Ave.	1910	252	29	6	11	27.0
Grand River Ave	1910	308	59	29	46	50.0
Michigan Ave.	1910	481	219	23	21	64.6
River Rd. Ave.	1910	149	49	6	2	41.6
Gratiot Ave.	1911	326	11	3	6	9.2
Grand River Ave	1911	515	13	3	6	9.3
Michigan Ave.	1911	1570	219	42	14	22.6
River Road	1911	434	165	13	9	44.9
Grand River Ave	1912	1208	70	13	5	10.9
River Road	1912	213	14	4	0	12.2
River Road	1912	208	17	0	0	10.0
Fort Street	1912	450	0	9	1	6.5

The defects appear on fills or in cuts, due either to settlement ~~on~~ water or frost in sub-grade.

Holes are due to courser material collecting in small nests and having insufficient mortar to bind together.

More general disintegration due to too fast drying or to freezing while setting.

1. Paper read by F.F.Rogers, Michigan Highway Com. at American Road Congress at Detroit.

The forces which cause cracks are:

(a) Temperature variation.

(b) Extraordinary heavy loads.

(c) Unequal settlement.

Temperature does not seem to be the cause, because if this were so all slabs would have approximately the same number of cracks. This is not so.

If heavy loads caused the defective work, there would be a large number of continuous cracked slabs. There is no evidence of this in Wayne County.

Mr. Johnson believes that defects are due to settlement of foundation combined with temperature and load stresses. He states that the cracks in a concrete road are a minute affair. They are easily and cheaply repaired by filling them with pitch. This presents an unbroken road surface.[1]

Up to the present time, the defects noted, except the pitted conditions of the concrete roads (surfaced with refined tar and fine gravel) are not serious and have not caused any additional cost of upkeep. [2]

In the past two years the expansion joints on all the old work, whether reinforced or not, have been recoated with refined tar and sand once a year. The cost has ranged from $50 to $100 per mile per year.

1. A.N.Johnson, Engineering-Contracting, Oct. 22, 1913.
2. F.F.Rogers, Engineering-Contracting, Oct. 22, 1913.

TYPES OF CONCRETE PAVEMENTS

(1) Hassam Compressed Concrete

(2) Concrete Cube Pavement.

(3) Concrete Simple Unit or Layer

(4) Simple Concrete Covered With Some Form of Bitumen.

(5) Reinforced.

(6) Dollarway.

1. HASSAM COMPRESSED CONCRETE

The Hassam pavement is constructed on a properly constructed subgrade. First a layer of proportioned stone is laid to a depth of 6 inches, and compacted by thorough rolling. A grout composed of 1 part cement to 2 parts sand is then poured upon the stone until the grout flushes to the top. A layer of pea stone is next evenly spread over the grouted layer and the rolling continued until the grout flushes to the surface.

On top of this surface is spread a 2 inch layer of trap rock. This is rolled and grouted as the bottom course except that a thin grout of 1 part cement to 2 parts sand is used.

A finishing coat composed of 1 part cement, 1 part sand and 1 part pea size trap rock is mixed thick and broomed into the voids. Rolling is continued until the pavement has a smooth surface.

The following table gives several examples of the Hassam type of construction.

TABLE IX.[1]

CITY	YEAR BUILT	SQUARE YARDS	THICKNESS INCHES	COST PER SQ.YD.
Niagara Falls, N.Y.	1911	1,200	6"	$2.00
Kansas City, Kan.	1911	40,000	6"	1.68½
Wichita, Kan.	1911	85,000	6"	1.69½
Portland, Me.	1907 to 1911	18,700	-	1.65 to 2.06
Haverhill, Mass.	1909	18,000	6"	1.75
Saginaw, Mich.	1908	9,000	-	1.40
Independence, Ia.	1910	32,000	6"	1.60
St. Joseph, Mo.	1910	90,000	6"	1.39
St. Joseph, Mo.	1911	39,000	6"	1.35
Niagara Falls, N.Y.	1912	32,300	7"	2.00

2. CONCRETE CUBE PAVEMENT

The roadway is first properly graded and drained, and a sand cushion of 1/4 to 1/2 inch in depth spread smoothly over the finished subgrade. Two inch concrete cubes, properly made and cured, are laid on this sand cushion. These cubes are then properly rolled to give an even and true surface. A sand filler is next applied and broomed into the joints. Four foot shoulders are constructed to hold the cubes from spreading.

Cubes for concrete pavements should be dried in racks for 24 hours and seasoned for three months before they are used in

1. Concrete Highways, Assn. of American Portland Cement Mfgs. 1913.

pavement construction.

A concrete cube highway was constructed near Rochester, N.Y., in 1909. 730,000 2-inch gravel concrete cubes were used in this pavement. The roadway was 15 feet wide and had a crown of 1/2 inch per foot of width. The road was subjected to very heavy and mixed traffic, and at the end of two years large areas of the pavement failed. There were 1,700 square yards constructed at a cost of 51¢ per square yard.[1]

3. CONCRETE SIMPLE UNIT OR LAYER TYPE

After the sub-grade has been graded to the proper elevation, compacted well by rolling and the drainage facilities properly treated, the roadway is ready for depositing the concrete.

The sub-grade is first watered so that the concrete will not be dried out rapidly when first deposited. The concrete is then mixed in the proper proportions and deposited by successive batches on the roadway. Sufficient water should be used to insure easy spreading with a template, but not to cause a separation of aggregate and mortar.

The concrete is brought to the proper grade by means of a template. The surface is then finished properly from a bridge. This compacts the surface and leaves it free from depressions or inequalities.

When the concrete has hardened sufficiently to prevent pitting, it is covered with a canvas to prevent rapid drying

1. Engineering Record,

out. This is later removed and a layer of earth or sand is spread over the pavement and kept wet and free from traffic for ten days.

Table X, follòwing, gives several examples of the simple unit type of pavement.

TABLE X.[1]

LOCATION	YEAR BUILT	SQUARE YARDS	THICKNESS INCHES	PROPORTIONS	COST SQ. YD.
Burlingame to San Francisco	1912	76,000	5"	1:3:6	$ 0.67½
Highland Park, Ill.	1912	15,000	5" & 7"	1:2:3½	1.01
Atlantic, Ia.	1912	13,400	6" & 7"	1:2:2	1.12
Bettendorf, Ia.	1911	29,000	6"	1:2:4	0.85
Burlington, Ia.	1913	34,400	6"	1:2:3	1.17
Kansas City, Ka.	1912	16,400	6"	1:2:4	1.00
Grand Haven, Mich.	1913	13,300	7"	1:4 excl. grading	1.05
Bemidge, Minn.	1912	19,800	5"	1:3½	1.05

The preparation of the sub-grade for the layer type is the same as for the one course construction. The concrete is mixed in the specified proportions, a 1:2½:5 being considered advisable. Successive batches of concrete shall be deposited immediately on the finished sub-grade. The concrete is well tamped to an elevation which will bring the top surfacing up to the finished grade.

The wearing course is mixed in the proper proportions,

1. Concrete Highways, Assn. American Portland Cement Mfgs. 1913.

one of cement to two parts of aggregate being found satisfactory. This wearing surface shall be deposited on the bottom course before this has set up hard enough to prevent a bond between surfaces. It should not be deposited later than fifty minutes after the bottom course has been laid. The surface is finished and cured as in the one course type of construction.

Milwaukee County has laid one course construction extensively in 1911, 1912 and 1913. The mixture used was 1:2:3½ and the widths varied, being 12, 16 and 18 feet. These roads have five foot gravel shoulders none of which are rolled. In sand these concrete roads are seven inches at the center and six inches at the side. In clay or loam the depth in the center is 8 inches with 7 inches at the side. One of these roads known as the Blue Mounds Road has beeb pronounced by experts as the best type of concrete construction in the country.

The average costs have been $1.10 per square yard for concrete and $1.22 per square yard for road including shoulders and grading.

Richmond, Ind., laid 34400 square yards of two-course construction at a cost of $1.48 per square yard. No maintenance costs have been incurred on any of Richmond's pavements to date. Many examples are found under the history of concrete pavements.

4. SIMPLE CONCRETE COVERED WITH SOME FORM OF BITUMEN

The simple concrete is laid as described and the surface thoroughly cleaned and dried. Bitumen is then applied to the pavement to the amount of 1/2 gallon per square yard. Hot sand is spread evenly over the pavement and a tandem rolleris used to compact this material. More sand is added until all the bitumen is taken up. The total depth of the sand is from 3/8 to 1/2 inch.

At Newark, N.J., up until 1912 there is on record approximately 120,000 square yards of bituminous concrete pavements, using an average of 6" in depth and costing $2.13 per square yard.

5. REINFORCED CONCRETE PAVEMENTS

Reinforced concrete pavements are built of either the one or two course construction. After the base of the two-course construction is completed, the reinforcing metal is laid directly upon the bottom course and lightly tamped, so as to be about half embedded in the concrete.

In the one-course construction the concrete, as in the simple type, is leveled off to a depth of two feet below the finished surface of the roadway. The reinforcing metal is laid and the wearing course of 1:1½:3 mixture is placed, finished and cured as in the simple type of construction.

The following table gives examples of reinforced concrete pavements constructed in Fond du Lac, Wis.

TABLE XI.

NAME OF STREET	SQUARE YARDS	PRICE
Merrill	8608	$1.24
Alcott	1897	1.20
Doty	13192	1.27
Sixth	11043	1.25
Third	2817	1.36

6. DOLLARWAY

The dollarway form of pavement differs from case 4 in that not less than one-third of a gallon of Dollarway bitumen is used per square yard of pavement, and sharp clean sand spread on the pavement using 1 cubic yard to 150 square yards of surface.

TABLE XII

DOLLARWAY PAVEMENT LAID IN ANN ARBOR, MICH.

YEAR	SQUARE YARDS	COST PER SQ.YD.
1909	1,883	$
1910	16,557	
1911	64,089	
1912	11,537	$.88 to .91
1913	50,000	

The roads were constructed on gravel sub-soil. The maintenance cost for pavements laid in 1909 was 7¢ per square yard per year. The cost of filling expansion joints was 10¢ per square yard.

TABLEXIII[1]

ESTIMATE OF THE COST OF ONE SQUARE YARD OF CONCRETE ROAD
7" THICK

Labor . . . . . 25¢ per hour,
Teams & Driver. 45¢ per hour.

ITEM	LENGTH OF HAUL IN MILES: 1/2	1	2	3
Supt., watchman, misc. labor	0.055	0.055	0.055	0.055
Shaping roadbed, trimming shoulders	.083	.083	.083	.083
Loading & Hauling material	.116	.153	.218	.296
Mixing and placing	.109	.109	.109	.109
Cost of Sand & Gravel at $1.50 per cu.yd. f.o.b. destination	.379	.379	.379	.379
Cost of cement, $1.20 bbl.	.364	.364	.364	.364
Expansion joints spaced 50' apart	.025	.025	.025	.025
Coal, oil, miscel. supplies for mixer	.007	.007	.007	.007
Forms and other lumber	.005	.005	.005	.005
Totals	$1.143	$1.118	$1.245	$1.323

6" THICKNESS

Totals	$1.003	$1.035	$1.091	$1.158

1. A. N. Johnson, State Engr. Illinois, Engr.-Contracting, May 22, 1913.

CHAPTER III

DESIGN

Before a road is designed or constructed it is necessary to know under what conditions of traffic it is to be used. A traffic census should be taken and inquiry made of the people living near by.

In order to obtain a fair report, a normal summer traffic, an abnormal summer traffic, and a normal winter traffic should be taken.

1st. Traffic reports should be taken six or seven consecutive days.

2nd. Distributing the recording days throughout a season. Monday of the first week, Tuesday of the second week, etc.

3rd. Traffic taken for a season from April to October, inclusive. These traffic reports to be taken for four periods of three days each.

One report taken in April, May and June, one in July, one in August, and one in September or October.

The first two plans would give only an abnormal or normal report, depending upon the month and weather conditions. The third plan is the most practical, efficient, and gives more nearly an average result.

The following are the most essential considerations which should govern the planning of an individual road or a complete highway system:

I. The road should be as direct as the topography and limiting grades permit.

II. Trunk lines should form the basis of a complete

road system.

III. Detours from the general direction of trunk lines to reach unimportant towns are not justified. Such towns can be served by branch lines.

IV. The principal streets of a city should form a part of the trunk system in which the city belongs. Facility of movement between city and surrounding country is essential.

V. Roads should increase as they approach important towns. This will save future expense in widening the streets.[1]

VI. At crossings or junctions of rural highways sufficient space should be added to the road to afford a view of approaching vehicles.[1]

WIDTH

The Wisconsin Highway Commission has found that for very heavily traveled sections the 14 or 16 foot roadway is desirable, while in localities where traffic is light a 9 foot roadway is sufficient. See Plates I and II.

TABLE XIII

TRAFFIC CONDITIONS

CHARACTER OF VEHICLE	MILES TRAVELLED	LIGHT TEAMS MET	LOADED TEAMS MET	MILES TRAVELED PER LOADED TEAM	MILES TRAVELED PER LIGHT TEAM	MILES TRAVELED LOADS & LIGHT
Light	230	66	142	3½	1.2/3	1-1/10
Loaded	104	32	53	3½	2	1-1/5
Totals	334	98	195	3-2/5	1-7/10	1-1/7

By the table we see that a loaded vehicle travels 3½ miles before meeting a loaded team, and 2 miles before meeting a light team.

1. Engr.-Contracting, Sept. 10, 1913.

With solid and well-made shoulders two vehicles can pass easily on a 9 foot roadway. Vehicles must slow down on a narrow roadway when passing. This is an advantage in building narrow roadways, as it saves maintenance costs and lossof life.

When important routes lead out of cities a 16 foot or even an 18 foot roadway is advisable until all feeder roads are passed. The 9 foot width will amply serve the purpose on branch roads and 14 foot on trunk lines.

CROWN

The crown should be from 1/8 to 1/4 of an inch to the foot of roadway. The Wayne County roads are now built with a crown of 1/100th of total width of concrete, while the Wisconsin Highway Commission favors a crown of two inches on all roadways. The crown should be only sufficient to carry off all surface water.

The following table gives the crown of streets in various American Cities.

TABLE XIV[1]

TABLE SHOWING CROWN OF STREETS IN VARIOUS AMERICAN CITIES

CITY	WIDTH OF STREET FEET	CROWN IN INCHES	RATIO CROWN TO WIDTH
Davenport, Ia.	24 - 32	6	1:48
do.	52	8	3:104
Dubuque, Ia.	10	2	1:60
Cresco, Ia.	29½ - 42	6	1:15 1:92
Vinton, Ia.	46	6	1:92
Council Bluffs, Ia.	20	1½	1:160
Clear Lake, Ia.	50	8	1:75
Cedar Rapids, Ia.	16	2	1:96
Cedar Rapids, Ia.	18	3	1:72
Mason City, Ia.	18	3	1:72
Mason City, Ia.	30	6	1:60
Mason City, Ia.	40	8	1:60
LeMars, Ia.	30	5	1:72
Rockville, Ind.	26	4	1:78
Menominee, Wis.	32 - 42	4	1:96 1:126
Fond du Lac, Wis.	24	3½	1:86
Fond du Lac, Wis.	27	4	1:90

1. Compiled from data received from Universal Portland Cement.

Current practice favors a maximum thickness at center of 8 inches, and a minimum of 7 inches. The sides of the pavement vary from 5 to 6 inches, in depth. These thicknesses depend upon the soil conditions and the traffic. On heavily traveled roads an average depth of 7 inches should be used, while the 6 inch depth is suitable for lighter traveled roads. In clay an average of 7 inches of concrete should be used while in sand where we obtain good drainage 6 inches is suitable.

EXPANSION JOINTS

Expansion joints have given the most trouble in concrete highway construction. Their width, length of sections and protection have been varied in experimental work.

Concrete is known to shrink 3/4 of an inch to the 100 feet in 6 months. This is as much as caused by a temperature change of over 100 degrees Fahrenheit. If this sudden drying out could be prevented many of these defects would be eliminated.

The average coefficient of expansion of concrete is about 0.000005 per degree Fahrenheit. In Wisconsin with a variatian of 100 degrees Fahrenheit the theoretical width of joints for various spacings would be as is shown in the following table.

TABLE XV.

JOINT SPACING FEET	WIDTH OF JOINT INCHES
30	3/16
40	1/4
50	1/3
100	5/8
150	3/4

Wayne County has experimented with several types of joints; two thicknesses of three-ply tar paper separated with a pine board, asphalt, still wax and pitch. The Baker armor plate has proved the most satisfactory and is used exclusively. These plates are of soft steel 3/16th of an inch thick and 3 inches wide. These are curved to conform with the finished surface of the roadway. Between the plates is placed 3 thicknesses of asphalt felt about 1/4 of an inch in thickness. These plates are anchored to the concrete by shearing out parts of the member at regular intervals.

COST OF STEEL PROTECTION EXPANSION JOINTS

Steel plates cost approximately 13¢ per foot of joint, f.o.b. points in Wisconsin.

Asphalt felt composition filler costs 1¢ per foot, f.o.b. points on railroad.

The entire time of 2 laborers will be required to do the joint work when from 200 feet or more of joints are laid in a

10 hour day.

Labor of filling joints . . 1-3/4¢ to 2¢ per foot of joint
Asphalt heated , ... 2¢ tp 3¢ per foot of joint.

When asphalt felt is used without metal protection the cost will be approximately that of protected joints with protection material deducted.

Wayne County expansion joints add 5¢ per square yard to the cost of the pavement.

MIXTURE

Concrete must be very dense and be able to withstand shearing and compressive and tensile stresses. A 1:1½:3 mixture of concrete has proven satisfactory and is used exclusively by Wayne County, which has constructed the greatest mileage of concrete roads. Wisconsin Highway Commission favor a 1:2:3½ concrete.

Concrete must be very dense so that no water will find its way to the subgrade. Too large a percentage of water is not recommended as the maximum strength of concrete is materially lessened.

MATERIALS.

It is necessary to use a concrete whose mortar content is rich in cement in order that a sound and strong concrete may be obtained. In general, limestone and similar soft rocks are not satisfactory, while quartzites and flint gravels are excellent.

Concrete pavements cannot go far wrong if the following requirements are adhered to.

(1) Selection of Portland cement conforming to the specifications of the American Society for Testing Materials.

(2) Sand, clean, sharp, course and well graded; 5% of finely divided clay is allowed.

Experiments at the University of Illinois show that the strength of concrete is not materially lessened by even 6% of finely divided clay. The cost of cleaning gravel is a large item and it is more economical to use a small percentage more of concrete.[1]

(3) Course Aggregate: Clean, hard and sound rock, gravel of good quality, or hard dense crushed furnace slag is recommended. Water should be free from strong acid or alkalies and the concrete mixed fairly wet.

SHOULDERS

Shoulders for concrete roads should be constructed of gravel containing sufficient binding materials or crushed limestone. The North Fond du Lac concrete road was constructed with 3 foot gravel shoulders on 14 foot road and 5½ foot on the 9 foot roadway. They were made flush with the concrete and sloped off to o at shoulder width. The present practice in Wisconsin is to use 5 foot shoulders not rolled on all roads. Wayne County, Michigan, constructs shoulders 3 feet in width and from 3 to 7 inches in depth, using either limestone or gravel.

1. Cement & Engr. News, Oct. 1913.

GRADE

The aim of the Wisconsin Highway Commission is to limit the grades on the roads to 6%. Most grades on through roads average 4 to 4½%. Concrete is adaptable to all grades and alignments.

CHAPTER IV

CONSTRUCTION

After the proper appropriation of money for the assigned road has been completed, the preliminary survey is made. Level and transit parties are sent into the field to run grades and line on existing roadway. These notes with suggestions as to local conditions of drainage, existing culverts, bridges and soil are forwarded to the highway office. The notes are plotted up, and new location of line and grade fitted, so as to give a proper distribution of material and within ruling grades.

The final survey party is then sent into the field, and the construction grades and line staked out. These stakes are offset from the new center line of the highway, so as not to be disturbed during construction. They are placed 50 feet apart on tangent and usually 25 feet apart on curves.

It has been found convenient to place these stakes near fences so as not to be disturbed by plowing, mowing or pasturage of cattle.

Even with the best grade of materials and design, a concrete road must have the best possible construction and inspection to prove satisfactory.

PLANT

The size of the plant used in any case depends upon the amount of work and time required to complete the construction.

According to good practice, a fair arrangement of plant seems to be the following:[1]

1. Foreman
3 men finishing sub-grade.
1 man preparing joints.
2 form setters
6 loading wheelbarrows
2 handling cement
1 engineman
1 hoistman
1 man at concrete spout
2 striking off concrete
1 finishing - trimming edges
1 general utility man.
1 water boy

Total 26 men - expense $63.00 per day

1 team hauling water
1 team hauling cement
1 steam mixer

This plant will be capable of constructing 600 square yards of pavement 6" in thickness.

SUB-GRADE

The preparation of the sub-grade demands careful consideration. The sub-grade must be first brought as near to grade as possible, so that materials can be hauled onto the roadbed. If the grading is heavy, it is well to use teams, plows and scrapers, or a steam shovel may be used economically, if the cut contains a large yardage. Most of the work in Wisconsin can be done economically by pick and shovel, a plow and sufficient teams and dump wagons, as most of the roads are laid practically upon the old roadbed. The elevations are taken from the stakes and distance to subgrade equal to depth of pavement measured down from this point.

As the improvement of the road attracts traffic and thereby increases the stresses in the sub-grade, every weak place must be remedied. Concrete has less resiliency than most other types of highway materials, and the stresses resulting from traffic are greatly increased. The brittle character of concrete demands an even, sound and well-compacted foundations. Depressions in the foundation cause settlement of the concrete and consequently cracks.

The center of the old roadway is generally well hardened by traffic while the sides are less compacted. It is necessary in this case to supply new material to the sides and compact it thoroughly, thereby approximating a foundation of uniform strength.

If the road is built on an old macadam or stone foundation, and the new alignment does not coincide with the old, the road should be harrowed, leveled and thoroughly rolled to give a uniform bearing surface. All soft places, stumps and boulders should be removed to a depth of at least 6 inches below the finished sub-grade.

DRAINAGE

Good drainage is very essential to concrete road construction. It is necessary that all water be carried to the ditches and not left to seep from shoulders under the road metal. Many different plans for drainage have been experimented with, and proven satisfactory.

The simple type of drainage is the side ditches running parallel to the center line of the highway. They are usually built at a minimum 18 inches to 24 inches below the grade of the finished road.

When the roadway is on a side hill a 4 inch tile drain is laid 3 feet below the center of the sub-grade. This trench is filled with a course material for 9 inches, with hay or straw for 3 inches, and the remainder of three feet with gravel or course broken stone. In cuts two drains are used one on either side of the roadway. This type of construction is used in Wisconsin at present.

The following drainage system was advocated by the Third International Road Congress.

Water often seeps from the shoulders under the concrete through a plane between the shoulder and the road metal. A shallow drain having a width and depth equal to a shovel is excavated under both edges of the pavement. This is filled with course material, so as to form a blind drain. At 40 or 50 feet intervals lateral blind drains are constructed to carry this seepage water to the side ditches.

CONSTRUCTION PROPER

After the sub-grade and drainage have been properly provided for, the concrete is laid. All irregularities in the sub-grade are levelled and the side forms staked to the proper grade. The proper mixture specified should be measured

in cubic foot boxes to guide the laborers in forming the proper proportions.

The materials are placed in the mixer and water added to give a fairly wet mixture. It is then deposited upon the finished sub-grade. The concrete is immediately finished to the proper grade by means of workmen using a strike-off board conforming to the crown of the finished roadway.

When the concrete is dumped upon the roadway, the mortar part usually flows to the edge of the pile, leaving a core of aggregate with insufficient binding material. This should be remedied by distributing the rest of the aggregate by means of rakes and mixing it with the mortar.

The surface finish is then applied by men working from a bridge resting on the side forms. The surface is floated generally with a large wooden tool so as to smooth all irregularities and leave it a little rough. If a rough finish is wished, a course wooden broom may be drawn across the pavement while working from the bridge. This applies to one course construction which has been generally considered the most practical and most universally constructed at present.

PROTECTION

As soon as the pavement has started to set up a canvas covering should be spread over the same. This is left until earth can be spread over the surface without injury to the concrete. It is then covered with a coat of earth, sand, sawdust or other available material, and kept moistened for

a period of ten days. The covering coat is then removed and the pavement cleaned, surfaced if called for, and opened to traffic.

CHAPTER V.

GEOLOGY[1]

The rocks of the State of Wisconsin are very old. Probably the building of the state was completed in the Devonian period,as no rocks of later periods are found within its borders. The glacial period came a few thousand years ago, and with these glaciers was brought a thin sheet of earth which was spread more or less evenly over the land to the south.

The surface of the State was divided by glaciers into two great slopes, Northern and Southern. The northern is sharp and relatively steep, sending the waters into Lake Michigan. The southern slope is much longer and more gentle. It carries on its surface the rivers which drain south into the Mississippi and southeast into Lake Michigan.

Diagonally across the southern slope from the northeast to the southwest extends a great shallow valley. This has played an important part in the history and commercial development of the state.

Across the central portion of the state from the east to the west is a low lying sandstone area. This is less fertile in places than the rest of the state. It is the receiving station of the water which supplies the artesian wells of southern Wisconsin.

North of this low sand stone area lies the highland region of igneous rock, overlying clay deposits of glacial origin. This has retained in many places water to form lakes

1. Case, Wisconsin Geology and Physical Geography.

and swamps.

South of the great sandstone area rocks and soil are more varied.

The glacier moved over the state in succession of advances and retreats, leaving traces which can be easily distinguished today. The unstratified deposits or moraines cover all of Wisconsin except the Driftless area. The stratified drift are found in three different forms in the state, Kame, Overwash plains, and lake bottoms. These contain the sand and gravel deposits.

Gravel and crushed stone are found at all parts of the state in great abundance.

In general the driftless area and a considerable part of the drift covered areas of southeastern Wisconsin is covered with a clay loam. This is derived from decomposition of limestone and accumulation of residual clay.

The central and western parts of the state are underlain by Potsdam and St. Peter sandstone. The soil is of a sandy loam, except where the later drift deposits have covered the true soil.

In the belt extending northeast and southwest in the Green Bay lowlands, underlain by Cincinnati shale, the soil is clay. This contains a considerable amount of sand.

Bordering the Great Lakes, there is a heavy deposit of red clay. This is mixed with sufficient lime to form a marly clay soil of heavy character.

Plate III shows the soils of Wisconsin.

CHAPTER VI

WISCONSIN'S FACILITIES FOR ROAD WORK

The legislature of 1911 passed a law in 1911 creating a State Highway Commission. An annual appropriation of $350,000 was provided for state aid in 1912 and the succeeding years.

The governor of the State advised by the senate was given the power to appoint three commissioners, who are to hold office for two years. There are two other members on the commission, an ex-officio member, the state geologist, and the dean of the College of Engineering. A highway and bridge engineer were also employed.

There are very good railroad facilities in the state. All gravel and stone companies have ready access to all parts of the state. The railroads will transport road materials used in the construction of highways at a freight rate of one-half cent per ton per mile.

Wisconsin is not a prairie state, although nearly one-half of its area is approximately level. The balance is a rolling country with only low hills and no mountainous or rugged areas.[1]

The area composed of hills over 300 feet in height is not more than 5% of the total area of the state. Forty per-cent is level upland, and about 50% is rolling country.

A wide and comparatively flat highland extends over the

1. Bulletin Wis. Geol. & Nat. Hist.Survey, NO. I, 1898.

the northern part of the state. This divide varies from 1000 to 1900 feet in height. About 9% of the total area belongs to the Lake Superior watershed and the remainder to the broad southeast, south and southwest slopes.[1]

1. Bulletin, Wisconsin Geol. & Nat. Hist. Survey, No. 20.

CHAPTER VII

CONCRETE EXPERIENCE

Wisconsin has not had the experience in concrete highways that other states have had. The first concrete highways constructed in Wisconsin were during the spring and summer of 1911 in Milwaukee County, at Fond du Lac and Appleton.

Milwaukee County laid 7 miles of concrete roads in 1911, 22 miles in 1912, and about 22 miles in 1913. These were constructed of the 1:2:3½ mixture and had widths of 12, 16 and 18 feet. All types of construction have 5 foot shoulders not rolled. The depths of concrete were 7" and 8" at the center and 6 and 7" at the sides.

One road was completed late in November of 1911 and this pitted up and was covered with bitumen which pealed off after a short time. No coating of any form is now used on concrete roads built by the state. Contract work has proved a failure, and now all work is constructed on the force-account system.

Milwaukee roads cost approximately $1.10 per square yard, exclusive of grading, and $1.22 per square yard including grading. No maintenance costs are recorded as yet on these roads The roads constructed in 1913 cost from $1.24 to $1.72 per square yard, depending upon local conditions. Screening of gravel has been no special problem in Milwaukee County.

Wayne County roads have been thoroughly discussed, and from the small amount of expenditure for maintenance, have certainly proven satisfactory.

On the Fond du Lac - Oshkosh Road some defective slabs developed. The cause of these defects was not due to mixture, design or supervision, but to a large percentage of clay which became imbedded in the mixture.

The Waukesha gravel was spread in piles in the center of the highway, so that no delay would be encountered when construction began.

Farmers and autoists driving over the road spread the gravel over the soft clay sub-grade. When construction began this was not removed and some defects in the 9 foot roadway developed. These were replaced by new concrete slabs.

As a whole the concrete roads constructed in Wisconsin up to the present time have proven successful and are giving much satisfaction to tourists, farmers and the traveling public.

The following tables are embodied to show the relative costs of construction and maintenance of different types of highways.

TABLE XVI

MAINTENANCE COSTS OF WISCONSIN HIGHWAYS[1]

KIND OF CONSTRUCTION	AVERAGE COST PER SQARE YARD	AVERAGE LIFE YEARS	AV.COST PER SQ.YD. PER YR. REPAIRS
Asphalt	$2.25	15	$0.07
Granite	3.03	25	0.03
Brick	2.00	15	0.02
Boulders	1.50	25	0.03
Gravel	.40	10	0.06
Macadam	.55	8	0.07
*Cement-Concrete	.95	30	0.01
Bituminous-Macadam	.60	12	0.02

*Estimated from Fond du Lac.

TABLE XVII

MAINTENANCE AND REPAIRS OF NEW YORK STATE HIGHWAYS[2]

YEAR	MILES	RATE PER MILE PER YEAR
1907	667	$309
1908	978	379
1909	1987	679
1910	2133	1001
1911	2623	387 Repair work not completed
1912	3100	1009

1. A.L.Luedke, Thesis, U.of W., 1913.
2. Bulletin 48, U.S.Dept. Agriculture.

TABLE XVIII

AVERAGE COST PER MILE OF IMPROVED ROADS IN VARIOUS STATES IN 1909[1]

STATE	GRAVEL	MACADAM	BITUMINOUS-MACADAM
Alabama	$1,483.	$2,525	$13,250
California	1,375	5,375	8,575
Florida	3,900	3,112	- -
Maine	3,687	9,022	- -
Maryland	1,000	8,192	- -
New York	5,950	9,496	- -
New Jersey	4,317	8,746	9,930
Pennsylvania	1,575	9,164	10,000
Wisconsin	1,135	2,978	- -

The average cost of macadam for 34 states was $4,938 per mile, which provided for a 13 foot average width and a 6 inch average depth.

The average cost of bituminous macadam for 10 states was $10,348 per mile, providing for a 15 foot average width and a 6 inch average depth.

1. Bulletin #41, U.S.Dept. of Public Roads.

TABLE XIX

COST OF MAINTENANCE OF ROADS OILED IN 1909 AND NOT TREATED SINCE[1]

NO.	YEAR OF ORIGINAL EXPENDITURE	AREA IN SQ.YDS.	LENGTH IN MILES	ORIGINAL COST PER MILE	COST PER SQ. YD.	COST PER MILE
1	1909	7,750	0.88	$9,750.	$0.082	$ 724.
2	1900	3,090	0.351	6,880.	0.077	682.
3	1897	8,530	.970	8,860	.0725	638.
4	1901	10,505	1.000	5,857	.0628	661.
5	1899-1904	30,000	3.409	6,550	.0581	512.
6	1904-1905	12,655	1.438	6,032	.0992	872.
7	1900-1906	51,640	5.868	7,076	.0787	693.
8	1895-1896	25,873	2.940	8,862	.0725	638
9	1907-1908	10,333	1.174	7,807	.0784	690

1. Bulletin #48, U.S.Dept. of Public Roads.

TABLE XX

COST OF SURFACE TREATMENT OF MACADAM ROADS IN THE PARKS OF WASHINGTON, D.C.

NUMBER OF ROAD	KIND OF MATERIAL	QUANTITY GALLONS	AREA IN SQ.YDS.	SQ.YDS. PER GAL.	COST PER SQ.YD.
1	Oil	2,300	7,500	3.26	$0.028*
2	"	4,000	19,000	4.75	.022
3	"	1,000	3,400	3.40	.027
4	"	700	8,600	12.23	.012
5	"	5,000	25,000	5.00	.021
6	"	10,600	43,560	4.11	.022
7	"	3,400	19,450	5.72	.019
8	"	[illegible],350	4,000	11.43	.013
9	"	1,000	1,680	1.68	.046**
10	Tar	6,000	11,400	1.90	.044
11	"	650	1,500	2.30	.038
12	"	1,600	3,560	2.23	.038
13	"	2,580	7,740	3.00	.031
14	"	2,400	8,100	3.39	.028
15	"	875	2,000	2.38	.038

* Second application
** First Application.

1. Bulletin #48, Office of Good Roads.

TABLE XXI

BRICK PAVEMENT CONSTRUCTED IN VARIOUS AMERICAN CITIES[1]

CITY	FOUND-A-TION	DEPTH OF FNDN.	CUSHION THICK-NESS	MAKE OF BRICK	FILLER	NO. OF SQ.YDS	COST PER SQ.YD.
Birmingham, Ala.	Concr.	5"	2" Sand	Graves Shale	Sand	47,500	$1.90
Decatur, Ill	"	4"	2" "	Danville	Cement & Asphalt	4,700	1.65
Decatur, Ill	"	6"	2" "	"	do.	24,275	1.85
Decatur, Ill	"	6"	2" "	Terre Haute	Asphalt	2,187	2.00
Joliet, Ill.	"	6"	6" "	Barr	Sand	6,000	1.65
Joliet, Ill.	"	6"	6" "	Barr	Sand	700	1.94
LaSalle, Ill	"	6"	2" "	Barr	Sand	8,000	1.60
Taylorville Ill.	"	6"	2" "	Spring-field	Asphalt	9,250	1.56
Grand Rapids, Mich.	"	6"	1½" "	Metropolitan	Cement Asphalt	15,950	1.80
Binghamton, N.Y.	"	6"	1½" "	Corning Shale	Cement	8,975	1.61

1. Gillette's Hand Book of Cost Data, p. 344-346

TABLE XXII

REPAIR AND MAINTENANCE EXPENDITURES IN THE STATE OF MASSACHUSETTS[1]

YEAR	TOTAL MILES	MAINTENANCE COST PER MILE
1905	548	$ 105
1906	610	112
1907	655	162
1908	702	327
1909	740	543
1910	784	642
1911	829	647
1912	880	676

1. Bulletin #48, U.S.Dept. of Agriculture, Office of Public Roads.

CONCLUSIONS

Concrete roads have been successfully constructed in Michigan, Illinois, Iowa and many other western states. Their maintenance costs are a minimum in road construction. New York State is paying approximately $1,000 per mile per year to maintain their highways, the greater percentage being macadam. Massachusetts paid approximately $660 per mile per year in 1910, 1911 and 1912.

Waterbound macadam costs on the average $.65 per square yard, while bituminous macadam will cost approximately 75¢ per square yard. The maintenance on these waterbound roads will however bring the cost equal to the cost of concrete construction in Wisconsin in approximately 5 years time. Bituminous macadam will hold up under traffic much longer. Concrete can be laid in Wisconsin at approximately $1.25 per square yard, exclusive of grading. The gravel deposits are very numerous and are well distributed throughout the state. Gravel costs from 30¢ to 50¢ per cubic yard at the pit, and the freight by railroad is 1/2¢ per ton per mile. Wisconsin has an abundance of inland lakes and rivers distributed well over the state. The topography of the country is very suitable to concrete road construction, being rolling and flat. The average rainfall is 32 inches and the average range of temperature is 100 degrees Fahrenheit. New York State has a much greater range and their costs of maintenance of all types of macadam have been startling.

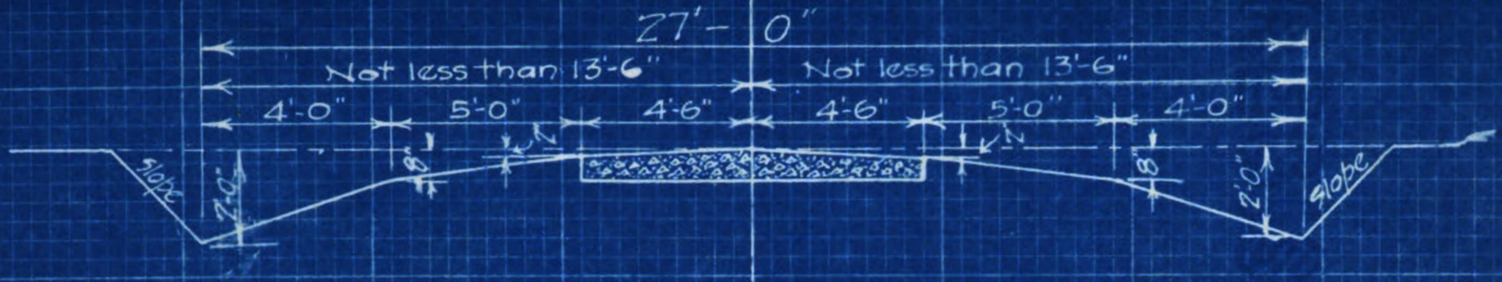
Cement production is rapidly increasing and its cost

is decreasing, as shown by the following plates numbered IV and V.

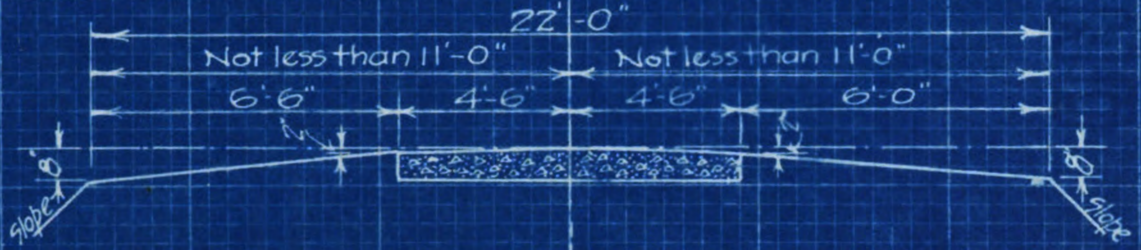
With the experience derived from Wayne County and the roads built in Milwaukee County, Wisconsin cannot err in building concrete roads. The abundance of gravel, water, the topography of the country and the low cost of maintenance, low cost of cement, and proximity of source of supply makes the concrete road the ideal type of construction in Wisconsin.

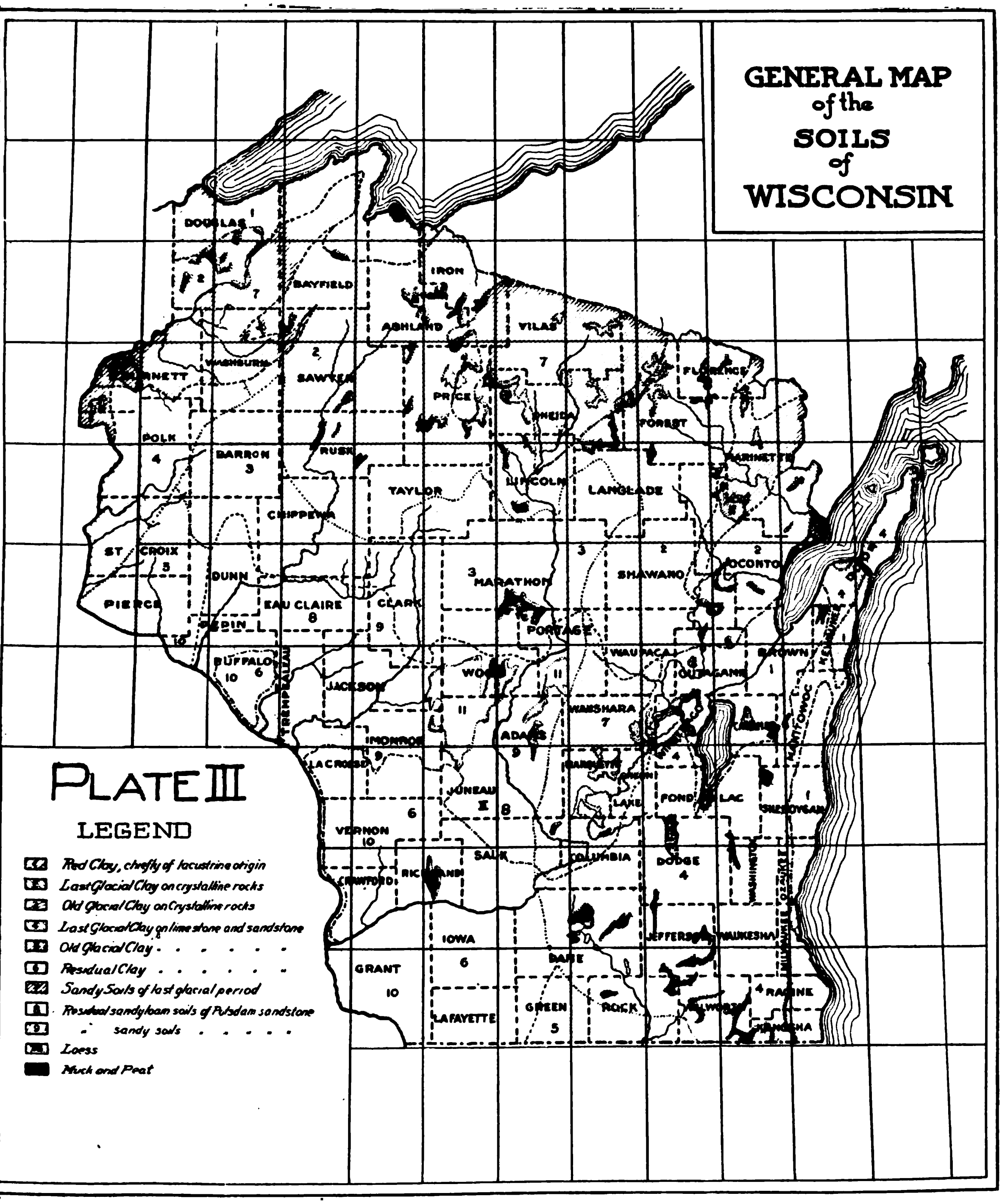
PLATE I

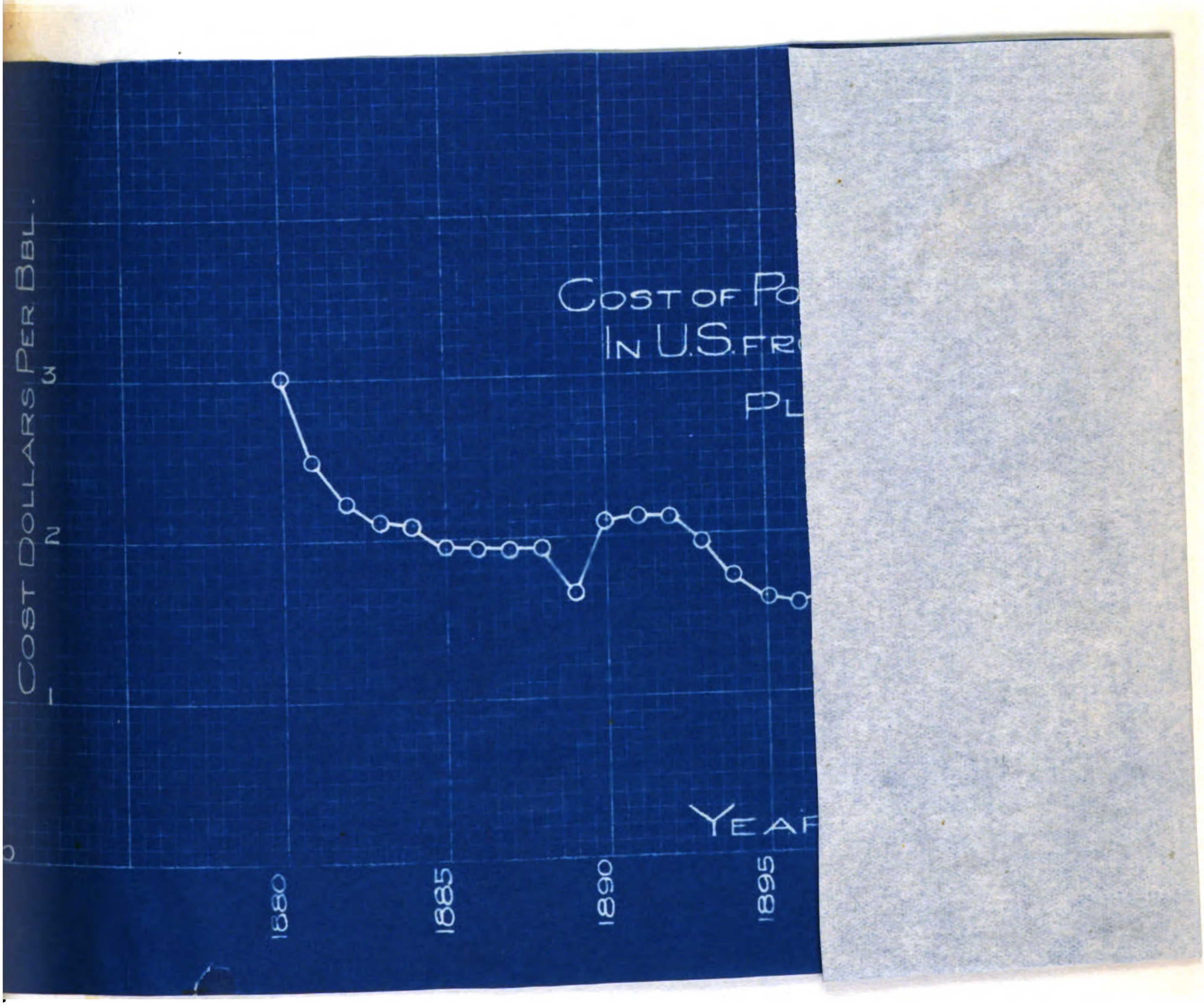
9 Foot Concrete Road
In Cut

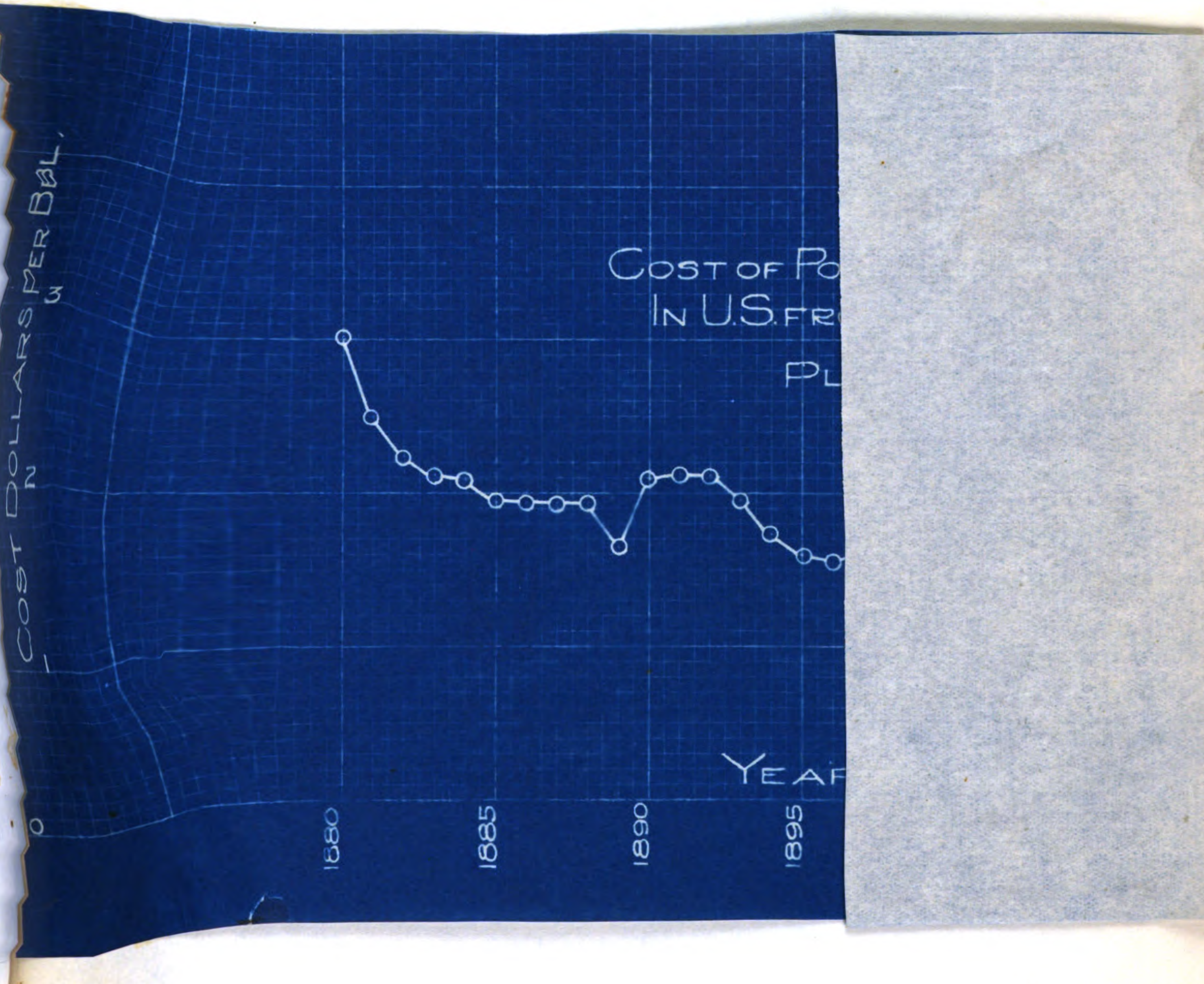


9 Foot Concrete Road
In Fill

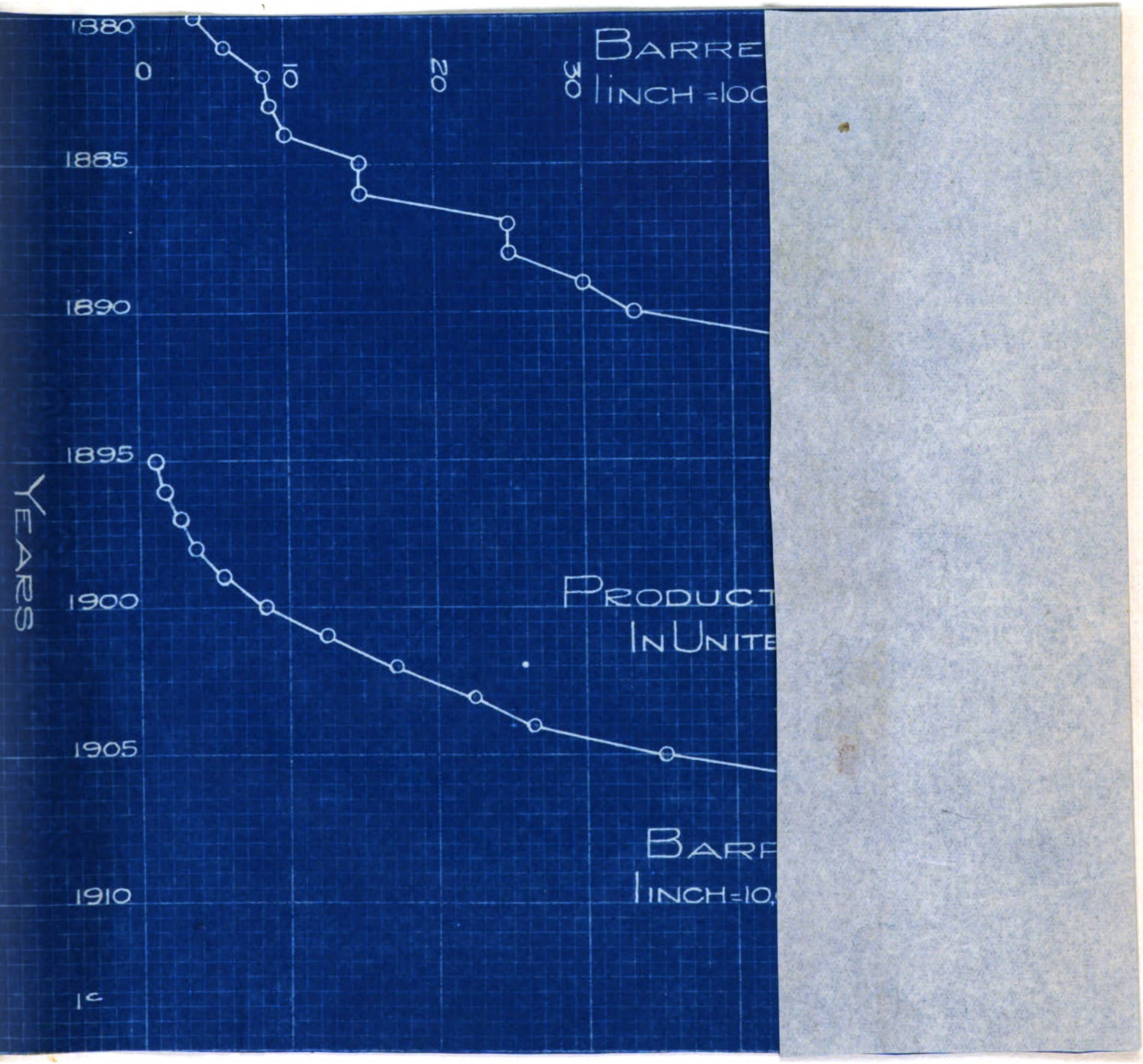



GENERAL MAP
of the
SOILS
of
WISCONSIN
PLATE III
LEGEND
Red Clay, chiefly of lacustrine origin
Last Glacial Clay on crystalline rocks
Old Glacial Clay on Crystalline rocks
Last Glacial Clay on lime stone and sandstone
Old Glacial Clay
Residual Clay
Sandy Soils of last glacial period
Residual sandy loam soils of Potsdam sandstone
sandy soils
Loess
Muck and Peat
DOUGLAS
BAYFIELD
IRON
ASHLAND
VILAS
FLORENCE
WASHBURN
SAWYER
PRICE
ONEIDA
FOREST
POLK
BARRON
RUSK
MARINETTE
TAYLOR
LINCOLN
LANGLADE
CHIPPEWA
ST CROIX
DUNN
MARATHON
SHAWANO
OCONTO
PIERCE
EAU CLAIRE
CLARK
PORTAGE
WAUPACA
BROWN
BUFFALO
JACKSON
WOOD
OUTAGAMIE
WAUSHARA
MONROE
ADAMS
LACROSSE
JUNEAU
FOND
LAC
SHEBOYGAN
VERNON
SAUK
COLUMBIA
DODGE
CRAWFORD
IOWA
JEFFERSON
WAUKESHA
GRANT
DANE
RACINE
LAFAYETTE
GREEN
ROCK
KENOSHA


Cost of
In U.S.
Cost Dollars Per Bbl.
3
2
1
0
1880
1885
1890
1895



COST OF PO
IN U.S. FR
PL
COST DOLLARS PER BBL.
3
2
1
0
YEAR
1880
1885
1890
1895



BARRE
1 INCH =10C
0
10
20
30
1880
1885
1890
1895
1900
1905
1910
YEARS
PRODUCT
IN UNITE
BARR
1 INCH=10,

Approved

Leonard S. Smith